

What is claimed is:

1 1. A manufacturing method of an arc tube in which a glass  
2 tube is formed into a double spiral by being wound around a mandrel,  
3 the manufacturing method comprising:

4 a softening step of softening the glass tube by heat;

5 a hanging and holding step of lowering the glass tube  
6 substantially perpendicularly so that the glass tube is hung  
7 with a part thereof being held on a top of the mandrel; and

8 a winding step of winding a remaining part of the glass  
9 tube around the mandrel.

1 2. The manufacturing method of an arc tube of Claim 1, wherein  
2 the glass tube is substantially straight before the  
3 softening step, and

4 the glass tube being substantially straight is heated  
5 so that a temperature of a double spiral scheduled portion is  
6 within a range between a softening point of the glass tube and  
7 150 degrees centigrade over the softening point inclusive, the  
8 double spiral scheduled portion being such a portion of the glass  
9 tube that is to be formed into the double spiral.

1 3. The manufacturing method of an arc tube of Claim 1, wherein  
2 the glass tube is substantially straight before the  
3 softening step, and  
4 the glass tube being substantially straight is heated  
5 so that a temperature of a double spiral scheduled portion varies  
6 in a lengthwise direction within a range of  $\pm 8$  degrees centigrade  
7 of a heating target temperature inclusive, the double spiral  
8 scheduled portion being such a portion of the glass tube that  
9 is to be formed into the double spiral.

1 4. The manufacturing method of an arc tube of Claim 1, wherein  
2 the mandrel is disposed beneath a substantially center  
3 of a double spiral scheduled portion, which is such a portion  
4 of the glass tube that is to be formed into the double spiral,  
5 and  
6 an axis of the mandrel extends substantially  
7 perpendicularly.

1 5. The manufacturing method of an arc tube of Claim 1, wherein  
2 the glass tube is substantially straight before the  
3 softening step, and  
4 the glass tube, being substantially straight, is held  
5 by ends thereof so that a tube axis of the glass tube is  
6 substantially horizontal.

1 6. The manufacturing method of an arc tube of Claim 1, wherein  
2 while the glass tube is substantially perpendicularly  
3 lowered, a portion in a vicinity of a center of a double spiral  
4 scheduled portion sags downward, the double spiral scheduled  
5 portion being such a portion of the glass tube that is to be  
6 formed into the double spiral.

1 7. The manufacturing method of an arc tube of Claim 1, wherein  
2 the mandrel has, on a periphery thereof, winding grooves  
3 that correspond to the double spiral, and  
4 a double spiral scheduled portion, which is such a portion  
5 of the glass tube that is to be formed into the double spiral,  
6 is positioned parallel with the winding grooves when viewed from  
7 a direction orthogonal to an axis of the mandrel, before the  
8 double spiral scheduled portion is wound along the winding  
9 grooves.

1 8. The manufacturing method of an arc tube of Claim 7, wherein  
2 ends of the glass tube are held by chuck units, and  
3 the double spiral scheduled portion is positioned  
4 parallel with the winding grooves by moving the chuck units in  
5 a direction that make the chuck units farther apart from each  
6 other, along a line that connects one of the chuck units with

7 the other of the chuck units when viewed from a direction toward  
8 which an axis of the mandrel extends.

1 9. The manufacturing method of an arc tube of Claim 2, wherein  
2 at least one pair of supporting rollers for supporting  
3 the double spiral scheduled portion is provided in a vicinity  
4 of the mandrel, and

5 the glass tube being in a soft state is substantially  
6 perpendicularly lowered so that the glass tube is disposed across  
7 the pair of supporting rollers.

1 10. A manufacturing method of an arc tube in which a glass  
2 tube is formed into a double spiral by being wound around a mandrel,  
3 the manufacturing method comprising:

4 a softening step of softening the glass tube by heat;

5 a hanging and holding step of hanging and holding the  
6 softened glass tube, by a substantially center thereof, on a  
7 top of the mandrel; and

8 a winding step of winding the glass tube on a periphery  
9 of the mandrel so that the glass tube is formed into the double  
10 spiral, wherein

11 ends of the glass tube being in a soft state are held  
12 by chuck units which each move toward the mandrel as the glass  
13 tube is wound around the mandrel, and

14           a first speed at which the glass tube is wound around  
15 the mandrel in the winding step is higher than a second speed  
16 at which the chuck units move.

1   11.    The manufacturing method of an arc tube of Claim 10,  
2   wherein

3           a ratio of the second speed to the first speed is no smaller  
4 than 0.6 and is smaller than 1.0.

1   12.    The manufacturing method of an arc tube of Claim 1, wherein  
2           the glass tube being in a soft state is guided into winding  
3 grooves of the mandrel by a pair of guiding rollers provided  
4 in a vicinity of the mandrel.

1   13.    The manufacturing method of an arc tube of Claim 12,  
2   wherein

3           the pair of guiding rollers is positioned so that an axis  
4 of each guiding roller is inclined at an angle of  
5  $\pi/2 - \alpha$  to an axis of the mandrel, where  $\alpha$  is an angle at which  
6 each of the winding grooves is inclined to the axis of the mandrel.

1 14. The manufacturing method of an arc tube of Claim 10,  
2 wherein

3 the glass tube being in the soft state is guided into  
4 winding grooves of the mandrel by a pair of guiding rollers  
5 provided in a vicinity of the mandrel.

1 15. The manufacturing method of an arc tube of Claim 14,  
2 wherein

3 the pair of guiding rollers is positioned so that an axis  
4 of each guiding roller is inclined at an angle of  
5  $\pi/2 - \alpha$  to an axis of the mandrel, where  $\alpha$  is an angle at which  
6 each of the winding grooves is inclined to the axis of the mandrel.

1 16. The manufacturing method of an arc tube of Claim 1, wherein  
2 while the glass tube is wound in the winding step, a gas  
3 for inflating the gas tube is sent into the glass tube being  
4 hung and held on the top of the mandrel, and

5 when the glass tube finishes being wound, a gas for cooling  
6 down the glass tube is sent into the glass tube.

1 17. The manufacturing method of an arc tube of Claim 10,  
2 wherein

3 while the glass tube is wound in the winding step, a gas  
4 for inflating the gas tube is sent into the glass tube being  
5 hung and held on the top of the mandrel, and

6 when the glass tube finishes being wound, a gas for cooling  
7 down the glass tube is sent into the glass tube.

1 18. An arc tube in which a glass tube is formed into a double  
2 spiral and which is manufactured by the manufacturing method  
3 of an arc tube according to any one of Claims 1 through 14.